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A categorical analysis of Weapon System Accuracy Trial (WSAT) data

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A Categorical Analysis of Weapon System Accuracy Trial (WSAT) Data

by

Brian F. Philipp
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1979

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I. INTRODUCTION

A. WEAPONS SYSTEM ACCURACY TRIAL (WSAT) BACKGROUND

1. History

The history of the Anti-Submarine Warfare (ASW) Weapon System Test program for surface ships dates back to post World War II studies of ineffective torpedoes, sensor alignment errors, and fire control accuracy problems. Presentation materials obtained from the Undersea Warfare Museum in Keyport, Wa. indicate initial systems level tests conducted on Dabob Bay, Washington as early as 1959 led to the establishment of WSAT tests and began the genesis of the surface ship ASW test program. Presently, WSAT is a total system test which demonstrates the ability of a ship's ASW combat system to pass prescribed equipment performance standards tests. The total test concept is shown in Figure 1.

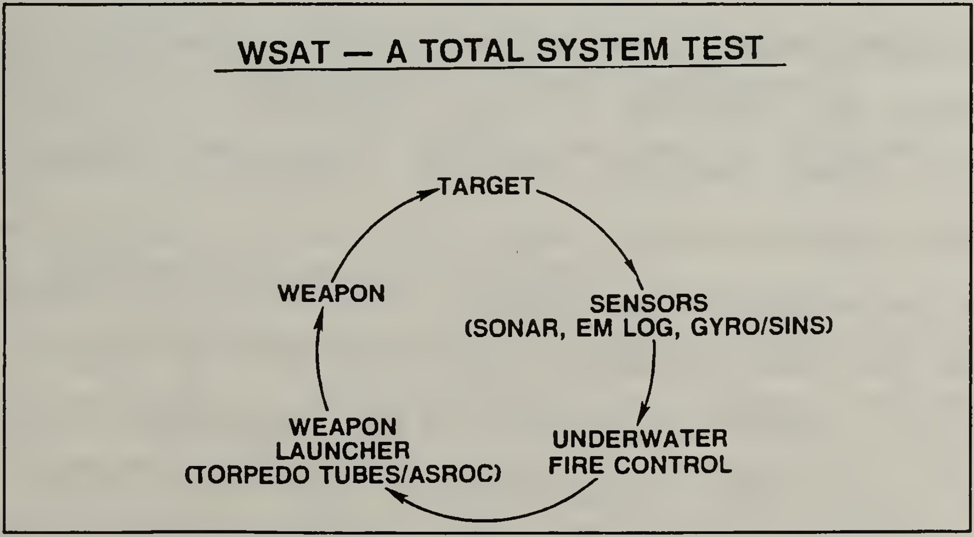


Figure 1. WSAT Overview

2. Responsibilities

Commander Naval Seas Systems Command (NAVSEA 06UT) has overall responsibility for WSAT and is the activity responsible for surface ship ASW system certification and recertification. The WSAT results are used by NAVSEA as a basis for granting this certification. ASW certification is required on every surface ship ASW combat system subsequent to new construction and commissioning. Similarly, ASW system recertification is required on existing surface ships which hold an ASW required operational capability upon exiting regular overhaul (ROH) or upon receiving a major ASW system suite upgrade in some other industrial period. Commander Naval Underwater Systems Center (NUSC), Newport, Rhode Island is designated as the WSAT program technical direction agent (TDA) responsible for all WSAT test and analysis procedures and documentation.

The WSAT organization supports both Atlantic and Pacific Fleet units. Surface ship WSAT inspections on the East coast are conducted by NUSC technicians at either the Atlantic Fleet Weapons Training Facility (AFWTF) 3-D underwater range near St. Croix with dockside tests at Naval Station Roosevelt Roads, Puerto Rico or at the Atlantic Undersea Test and Evaluation Center (AUTEC) 3-D range in the Bahamas with dockside tests done in Port Everglades, Florida. Surface ship WSAT inspections on the West coast are

accomplished by technicians from Naval Undersea Warfare Engineering Station (NUWES) detachment San Diego, California on the San Clemente Island 3-D Underwater Range (SCIUR) with dockside tests at Naval Station San Diego or Naval Station Long Beach. In the Hawaii area, inspections are done by NUWES detachment Hawaii on the Barking Sands 3-D Tactical Undersea Range (BARSTUR) with dockside tests done at Naval Station Pearl Harbor.

3. Objectives

NAVSEA Publication OD 40087 [Ref. 1:pp. 1-1], the ASW WSAT program manual defines the objectives of the WSAT program as follows:

- To ensure each surface ship ASW system reaches the fleet in satisfactory condition and is able to meet its assigned operating capabilities.
- To identify system defects prior to the expiration of contractual industrial warranties.
- To develop and analyze data on system specifications and tolerances and refine the same.
- To identify the appropriate command or agency responsible when system discrepancies degrade performance.
- To promote meaningful system improvement programs.

4. Inspection Sequence Of Events

When the Type Commander requires a WSAT conducted on one of his ships it is accomplished via request through the Fleet Commander scheduling system in conjunction with the responsible WSAT agency. The responsible activity then

assembles a stock test plan for the ship based on its configuration. Accordingly, the scope of the inspection varies, based not only on the ASW suite installed, but also on the inspectors available at inspection time. The WSAT consists of four inspection phases culminated with exercise weapons firings on an instrumented 3-D range to evaluate total ASW system dynamic performance. The WSAT consists of both dockside and underway testing, evaluation, and analysis. A summary of each WSAT inspection phase is provided as follows:

- Phase I (5-7 Days Dockside)
  1. Arrival conference and equipment set up.
  2. ASW fire control operability and accuracy checks.
  3. Internal sonar alignment checks.
  4. ASW system interface tests and alignments.
  5. Gyrocompass and inertial navigation error tests.
  6. Onload of exercise weapons and range instrumentation.
- Phase II (1 Day Dockside)
  1. Fire control and torpedo tube interface tests.
  2. Tube firing voltage and launch pressure tests.
  3. Dummy MK-46 torpedo firings on each tube.
  4. Measurement of weapon exit velocity.
  5. Weapon recovery, inspection, and preset verifications.
- Phase III (1-2 Days Underway)
  1. 3-D range Sensor Accuracy Test (SAT)
  2. Calibration of electromagnetic log.
  3. Gyroscope and inertial navigation heading checks.

• Phase IV (1 Day Underway)

1. Total system end-to-end test on 3-D range.

2. MK-46 over the side exercise torpedo firing.

3. Exercise ASW rocket (ASROC) firing from each launcher.

4. Helicopter exercise torpedo firing (if so equipped).

A summary of WSAT exercise firings is provided in Figure 2.

LAUNCHER CAPABILITY	NEW CONSTRUCTION	REGULAR OVERHAUL OR 4 YEAR SRA
SVTT only	2 OTS	1 OTS
SVTT and LAMPS MK III	2 OTS 2 LAMPS	1 OTS 1 LAMPS
SVTT and ASROC	2 OTS 2 ASROC	1 OTS 2 ASROC
SVTT, ASROC and LAMPS MK III	2 OTS 2 ASROC 2 LAMPS	1 OTS 2 ASROC 1 LAMPS
SVTT, DUAL ASROC LAUNCHERS	2 OTS 4 ASROC	1 OTS 4 ASROC
SVTT, DUAL ASROC LAUNCHER and LAMPS MK III	2 OTS 4 ASROC 2 LAMPS	1 OTS 4 ASROC 1 LAMPS

Figure 2. WSAT Firing Exercise Summary

Upon completion of the WSAT , test results are promulgated in the following manner:

- WSAT quicklook message report (24 Hours)
    1. Identifies all major, uncorrected discrepancies.
- WSAT final message report (10 Days)
    1. Identifies all remaining uncorrected deficiencies.
    2. Recommends corrective action on problems.
    3. Provides NAVSEA recommendation for certification.

5. Record Keeping

After the WSAT final report message is received by the cognizant inspection activity it is tracked until major discrepancies prohibiting certification are cleared (if certification is not initially achieved). At that time NAVSEA issues a certification statement for the ship concerned. Then the inspecting activity files the hard copy of the WSAT final report message in its respective technical library. NAVSEA (06UT) then utilizes the ASW test program data base for storage of pertinent WSAT information. NAVSEA, NUSC, and NUWES detachments are the holders and users of this microcomputer based data base. It will be described and evaluated in Chapter III of this analysis.

B. WSAT PROBLEMS

1. Cost

In recent years funding limits have precluded accomplishment of WSAT on all required ships, particularly those older ships exiting an industrial environment. Interviews with officials at NAVSEA have clarified the policy that all ships with ASW missions will receive WSAT or some reduced scope facsimile thereof rather than inspect just a few ships with a complete WSAT. Currently, AEGIS and BURKE class new construction and SPRUANCE class ASW suite conversions are receiving priority for funding. As a result of funding problems, older, less ASW oriented, ships such as non-AEGIS class cruisers and PERRY class guided missile frigates may not be funded for recertification inspections as they exit regular overhaul or other such industrial availabilities.

SUMMARY

TEST	LOC	FY 92
WSAT - SHIPS WITH LAMPS III (WITH ASROC)	SOCAL	123.6
	HAWAII	156.2
WSAT - SHIPS WITH LAMPS III (W/O ASROC)	SOCAL	120.6
	HAWAII	151.8
WSAT - SHIPS W/O LAMPS	SOCAL	110.1
	HAWAII	118.6
WSAT - SUBMARINES	SOCAL	138.2
	HAWAII	157.4
WSAT (WESTPAC) - SURFACE SHIP/SUBMARINE	HAWAII	189.1
WSAT FIXED COSTS (ANNUAL)	SOCAL	68.3
	HAWAII	63.5
SAT - SURFACE SHIP (1 DAY)	SOCAL	23.7
	HAWAII	29.1
SAT - SURFACE SHIP (2 DAYS)	SOCAL	27.9
	HAWAII	38.0

Figure 3. West Coast Cost Data (Thousands)

This is of concern since most of these ships are tentatively scheduled to remain on the active duty roster through the year 2000. Figure 3 provides fiscal year 1992 budget estimates of West coast WSAT costs based on required inspections forecast in the ASW test program data base. Force downsizing will be providing relief with the ongoing decommissioning of all KNOX class frigates as well as the COONTZ and ADAMS class guided missile destroyers. As for the non-AEGIS cruisers of the LEAHY and BELKNAP class which will remain on active duty in the near future, the *April 1992 Navy Times* [Ref. 2:p. 4] outlined Washington Navy proposals to possibly remove or at least deactivate sonar and ASW weapons systems from these ships. This effort will cut operations and maintenance costs and take a step toward eliminating obsolete systems from the fleet. It would also free up additional training facilities ashore and provide cost savings in the manpower area. The overall result with respect to ASW test programs would be fewer ships to certify.

2. Redundant Inspections

An additional problem effecting complete funding of required WSAT inspections is that of redundant inspections. The current impetus at NAVSEA is to eliminate redundant inspections, or at least to consolidate testing where possible to promote greater fiscal efficiency. An example of this is the AN/SQS-89(V) surface ship ASW suite certification. This

initial acceptance certification, which contains many of the same testing elements as WSAT, pertains to new ship construction programs and is intended to ensure specifications are met satisfactorily. This program is an important part of acquisition quality assurance policies in the Navy's dealings with outside vendors. Interview with Mr. Bob Devon of NAVSEACENPAC indicates that early timing of this certification with respect to crew training and arrival onboard from precommissioning sites may preclude substitution for WSAT in whole. However, some portions of the testing are candidates for consolidation in WSAT testing. Another example of this is the ASW Systems Qualification Trials (SQT), a part of the greater Combat System Shipboard Qualification Trials (CSSQT). Defined under NAVSEAINST 9093.1A, CSSQT encompasses the entire weapons suite and is heavily oriented to both operations and maintenance training. Although a favorite of the fleet due to the expansive scope of services, exercise shots, and training opportunities, NAVSEA has emphasized its responsibility for material readiness and not for training. Although no cost figures were available on CSSQT or ASW SQT, it is certain that costs are several times that of WSAT alone. Despite the fact that CSSQT and ASW SQT meet all requirements for WSAT, the certification processed is subject to competing demands in other combat systems areas. Likewise, WSAT inspection scheduling and budget controls at NAVSEA (06UT) are relinquished under CSSQT cognizant authorities.

As of January 1992, CSSQT and ASW SQT are unfunded for the foreseeable future with the exception of lead ships in a new class such as the BURKE class guided missile destroyer.

3. Reduced Scope Inspections

In an effort to provide a WSAT for every ship when due, the current effort is to develop a reduced scope inspection which will meet certification requirements. Specifically, the requirement for recertification after ROH or DSRA is of interest because statistically these were the ship inspections left unscheduled due to funding constraints. The first endeavor for a reduced scope WSAT inspection was the Surface ASW System Test (SAST). The *SAST Program Manual* [Ref. 3:p. 1-2] outlines the scope of the inspection. Figure 4, taken from that manual, displays the proposed relationship of the SAST program to the ship operational life cycle.

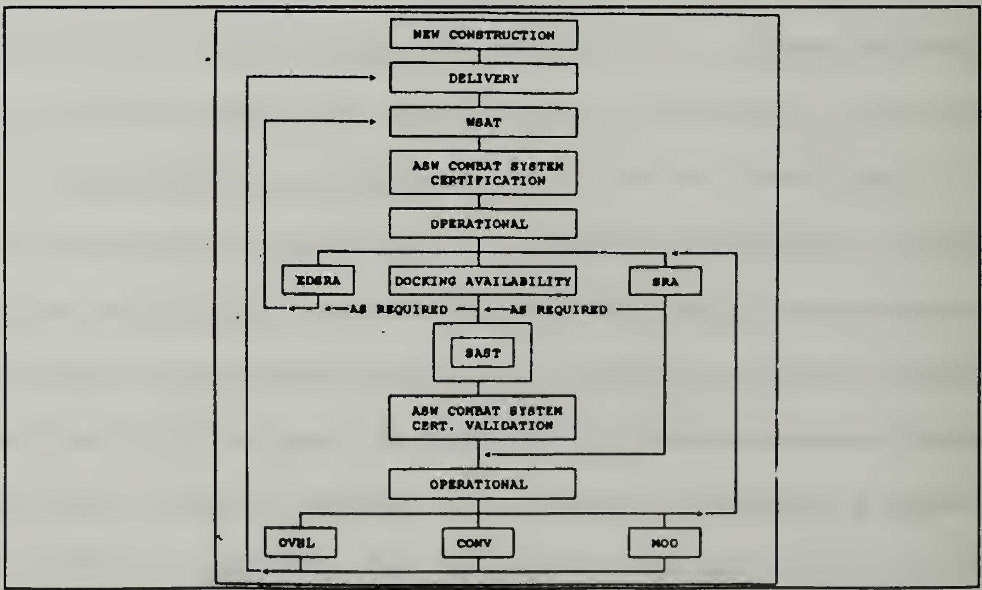


Figure 4. Ship Life Cycle (SAST)

The first SAST inspection was accomplished in January 1992 at Long Beach Naval Station, California aboard the USS PAUL F. FOSTER (DD-964). The SAST inspection was designed to cost approximately one third that of a WSAT and provide a reasonable assurance that the ASW combat system is ready for underway operations and meets requisite performance specifications. Although the four phase SAST inspection is similar to WSAT on paper, some significant differences exist. First, a shift of emphasis from outside source technician testing to ship's force requires that the ship complete Phase I dockside testing prior to the arrival of NUWES/NUSC ASW system experts in phase II. As a result, ship's force PMS checks now form the basis for continued testing. This assessment is performed by the SAST team leader. This concept removes the necessity of a WSAT team from being on travel for the usual WSAT phase I (5-7 days) dockside tests. Unfortunately, it shifts the foundation for ASW certification to the command involved without regard to current ship manning and training levels subsequent to an industrial availability when they are historically under strength. As a result some material categories could receive little or no attention by the more qualified NUSC/NUWES engineers in phase II, based on erroneous testing by ships force early in phase I. Additionally, the phase IV WSAT 3-D range firing exercises are eliminated. This concept eradicates the total system end-to-end test deemed important by the fleet as well as test

engineers. Also, it is unclear if anywhere in SAST an effort is made to scientifically determine where to concentrate scarce inspection dollars based on material discrepancy trends or histories. The latest endeavor at NAVSEA in restructuring WSAT, currently in the planning stage only, is referred to as the Consolidated ASW Test (CAT) program. The current surface ship ASW test plan POA&M is shown in Figure 5.

SURFACE SHIP ASW COMBAT SYSTEM CERT PROGRAM POA&M

DEC 91	Establish mimimum trial requirements
JAN 92	Define dockside requirements (Pt 1, Pt 2) Underway requirements
FEB 92	Prepare typical PMS test pkg (for dockside Pt 1)
MAR 92	Review PMS test pkg (TYCOMs, NAVSEA)
APR 92	Prelim test plan & daily schedule
MAY 92	Review test plan/schedule (by TYCOMs, NAVSEA)
JUN 92	Final/approved test plan/schedule
JUL 92	Schedule first ship for CAT trials
AUG 92	Brief first ship on CAT
OCT 92	Conduct first CAT trials
OCT 92/ DEC 92	Monitor, evaluate effectiveness of CAT Propose revisions and improvements

Figure 5. ASW Test Program POA&M

The goal of the CAT program appears similar to SAST in that it will define the post-shipyard ASW combat system certification program for surface ships. The program will meet OPNAV requirements to consolidate redundant inspections as well as address fleet concerns for collateral training opportunities alongside NUSC/NUWES technicians in both operations and maintenance. The process is currently under Total Quality Leadership (TQL) review to provide quality performance indicators which measure effectiveness and ensure ongoing program improvement. The lessons learned from the only SAST inspection performed will be incorporated by increasing NUSC/NUWES supervision during phase I dockside testing. As in SAST, increased reliance on ships force personnel in conducting selected maintenance checks will be utilized. This program will attempt to incorporate the existing ship PMS schedule with results from applicable shipyard testing to reduce or eliminate redundant and excessive testing. However, the program core testing requirements do not specify any analysis of systems discrepancy histories in regard to constructing individual ship test packages. Similar to SAST, elimination of 3-D range torpedo exercises are sacrificed in lieu of simulated ASROC, OTS, and LAMPS exercises.

4. Ramifications and Concerns

The overall thrust of the new ASW systems test program appears to make the best of a bad situation with regard to budget shortfalls. Funding of testing for new construction BURKE class guided missile destroyers will undoubtedly be preserved, the problem lies with recertifying the aging SPRUANCE and PERRY class ships. Likewise, the AEGIS cruisers of the TICONDEROGA class will also require some type of recertification inspection as they progress through their life cycle. The last ship of this class was commissioned in July 1992. The shifting of testing prerequisites to ships force as a prelude to ASW certification will pose another scheduling problem for afloat commands. This problem can be minimized by adequate involvement of the type commander and NAVSEA when planning ship overhauls. Additional efforts on the part of the ship will be required to ensure a core of sufficiently trained technicians are onboard at certification time. This will minimize possible compromise of initial phase dockside testing by unqualified technicians under pressure to meet schedule deadlines. A resounding need for ongoing statistical analysis in material category reliability is called for to prevent planned testing initiatives from risking overlook of problematic areas in construction of a ship test package.

C. THESIS OBJECTIVES

1. Material Discrepancy Data Analysis

With the substantial data available on WSAT ASW combat system material discrepancies, the first objective of this thesis is to perform a categorical data analysis to reveal which material categories are most prone to failure. This would refute an implicit assumption that all material categories are uniformly degraded and that reduced scope inspections need not statistically consider system material histories during program conception.

2. WSAT Data Base Examination

The second objective of this thesis will be a critical examination of the existing WSAT data base. This examination will include recommendations for future modifications to the data base; primarily with respect to the deletion and addition of specific data fields. These recommendations will be biased toward what will be required to make the data base a viable tool in future statistical analysis.

II. WEAPON SYSTEM ACCURACY TRIAL (WSAT) DATA

A. DATA COLLECTION

1. Experience Tour

During the six week ASW curriculum experience tour in quarter 5 of 8, several invaluable point of contacts were made to facilitate WSAT thesis data collection. Mr. Edward Biery of NUWES detachment Keyport, WA. (code 56) was sponsor of the experience tour. It was his office from which most background information on the WSAT program was obtained. That office arranged a visit to NAVSEA (06UT), Washington, D.C. to meet senior civilian engineers in the ASW test program as well as STGCS(SW) W.J. Vick, developer of the NAVSEA ASW test program data base. During this visit NAVSEA policies and goals with respect to the WSAT program were discussed and clarified.

2. Data Sources

The actual data for use in this analysis was obtained from various subordinate activities to NAVSEA. Specifically, the data was obtained in naval message format from the following activities:

- Pacific Fleet Data

    1. NUWES detachment, San Diego, CA. (code 906), Mr. Alex Rios (Head ASW Analysis Division).

    2. NUWES detachment, Hawaii (code 90), Mr. Adolph Neumann (Director Pacer).

- Atlantic Fleet Data

  1. NUSC Newport, R.I. (code 38), Mr. John Peters (ASW Test Analyst)

A summary of the WSAT data received for this analysis is provided in Figure 6.

WSAT DATA SOURCES BY SHIP TYPE

SHIP TYPE BY CLASS	NUMBER OF SHIPS TESTED
GARCIA (FF)	1
KNOX (FF)	9
USCG (WHEC)	4
BROOKE (FFG)	2
PERRY (FFG)	13
SPRUANCE (DD)	16
KIDD (DDG)	3
BURKE (DDG)	1
LEAHY (CG)	2
TICONDEROGA (CG)	13
TOTAL NUMBER OF SHIPS TESTED	64

SURFACE SHIP WSAT DATA (5 YEARS)

Figure 6. WSAT Data Sources

B. DATA ORGANIZATION

1. Data Specifics

A total of 64 WSAT final inspection report messages covering the last five years were obtained from cognizant inspection activities for use in this analysis. The data represents both Pacific and Atlantic fleet surface assets which have ASW as one of the command primary warfare areas. The last five years of data was chosen for this analysis:

1. To minimize interruption of business at the various inspection activities who were called on to locate, reproduce, and ship the data.

2. To minimize wasteful receipt of older data which is representative of ships scheduled for upcoming decommissioning.

The 64 final report messages contain a total of 595 inspection discrepancies. These data elements chosen for analysis are a representative population sample of all WSAT discrepancies. Each data element represents a failed maintenance inspection or operational check. For purposes of the categorical data analysis to be discussed in Chapter IV, each check is the result of a failed binomial experiment. The sampled data was further assigned to one of five specific material categories. The categories were not chosen arbitrarily, but rather were chosen per the prescribed categorical reporting format of the final report message described in *NAVSEA OD 40087*. With all inspection reports describing both major and minor

discrepancies in this manner, aggregation of all data elements into appropriate categories became a less arduous administrative task in bookkeeping.

2. Data Categories

To clarify which material discrepancies belong to specific categories, a breakdown is summarized as follows:

- Category I (Sonar Systems)
    1. Hull mounted sonar systems
    2. Towed array sonar systems
    3. Signal processing systems
- Category II (ASW Aviation Systems)
    1. Sonobuoy systems
    2. ASW helicopter data link systems
    3. Torpedo loading, arming, and presetter systems
- Category III (Weapons Delivery Systems)
    1. Surface vessel torpedo tubes, all makes and modifications
    2. Asroc box launcher systems
    3. Asroc guided missile launcher systems
    4. Asroc vertical launch systems
- Category IV (ASW Fire Control Systems)
    1. The Mk-114 analog fire control system
    2. The Mk-116 digital fire control system
    3. The USCG Mk-309 fire control system

- Category V (ASW Sensor Subsystems)
    1. The ship electromagnetic log
    2. Ship gyroscope and inertial navigation systems
    3. ASW related command decision systems (CDS/NTDS)
    4. ASW related gunfire control radars and systems
    5. ASW related consoles and repeaters

C. DATA SUMMARY PRESENTATION

For presentation of the data by categories bar graphs were chosen for relative comparisons between material categories. For this analysis the data is broken down by Atlantic and Pacific fleet and also shown Navy wide in Figures 7, 8, and 9.

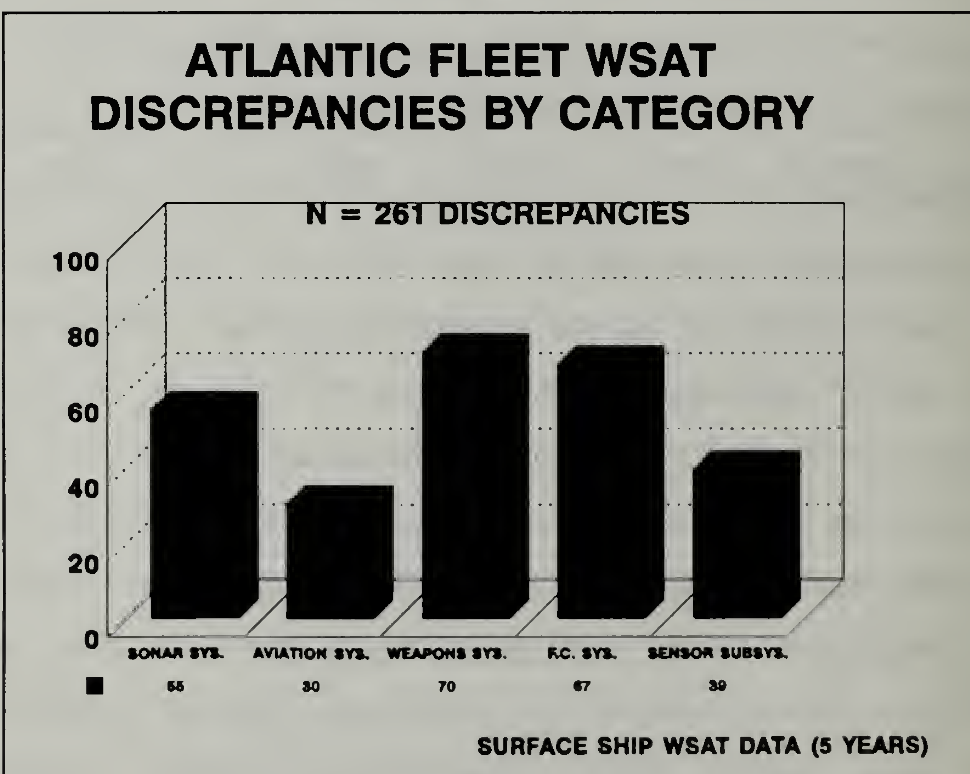


Figure 7. Atlantic Fleet WSAT Data

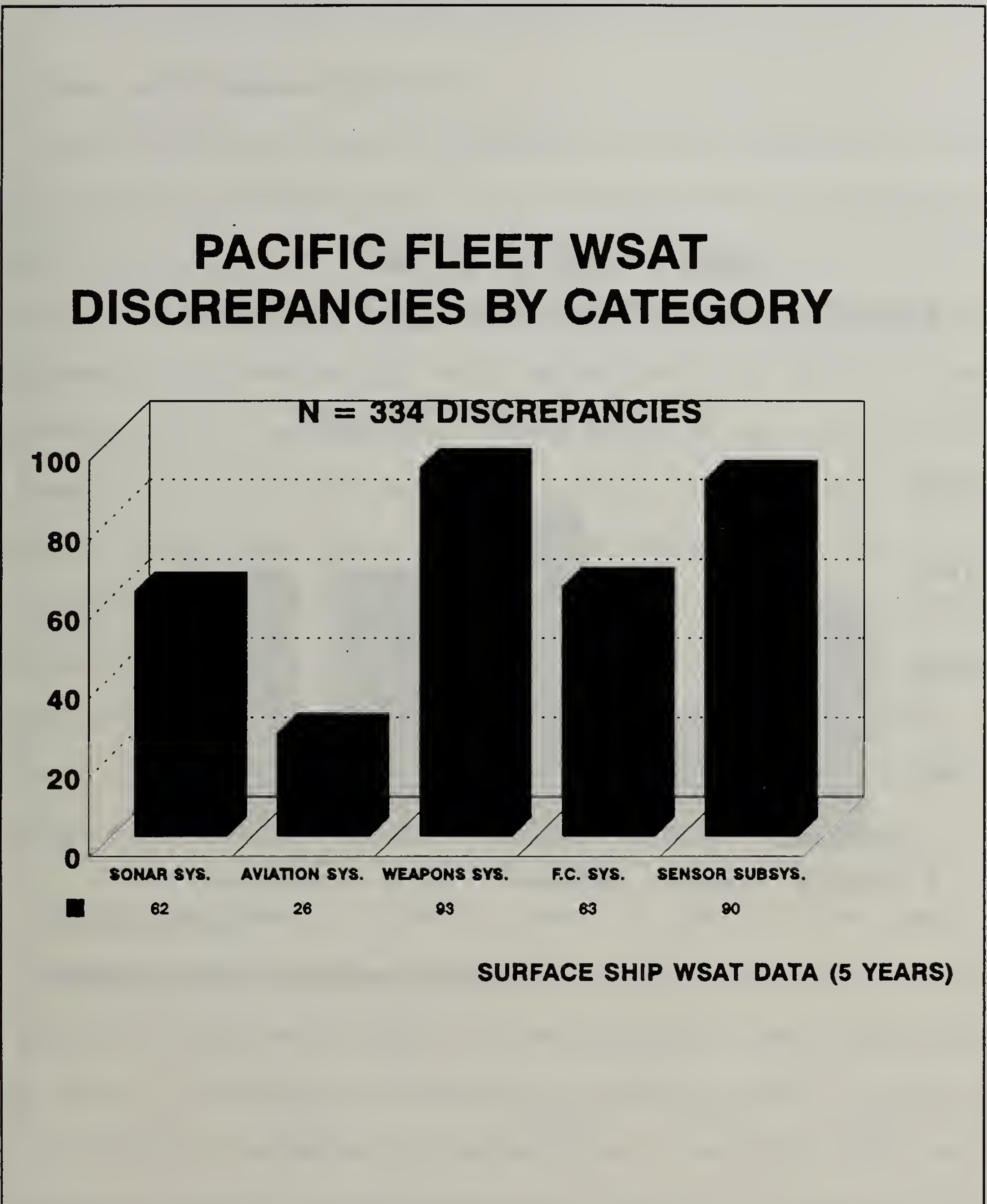


Figure 8. Pacific Fleet WSAT Data

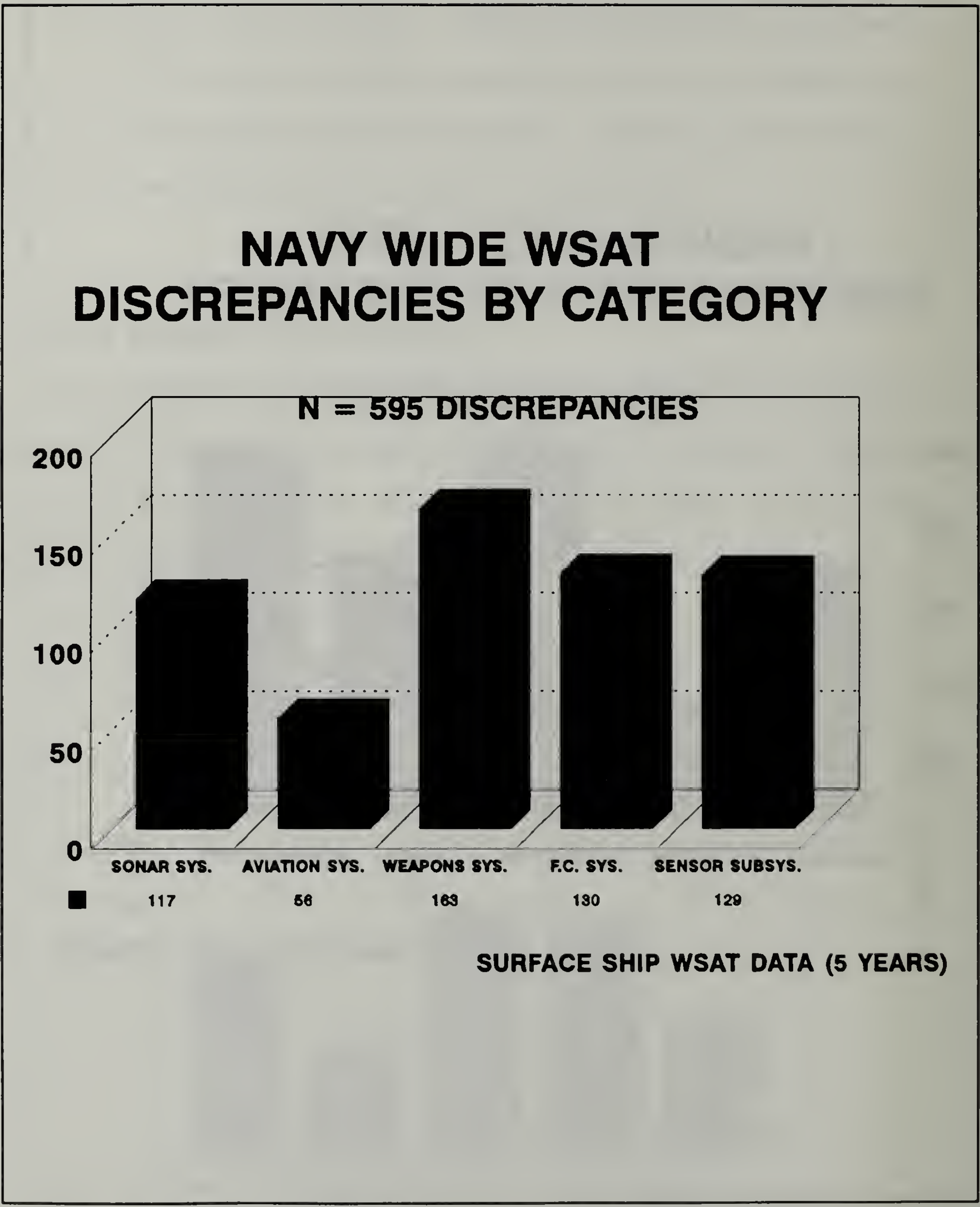


Figure 9. Navy Wide WSAT Data

III. THE WSAT DATA BASE

A. DATA BASE RESPONSIBILITY

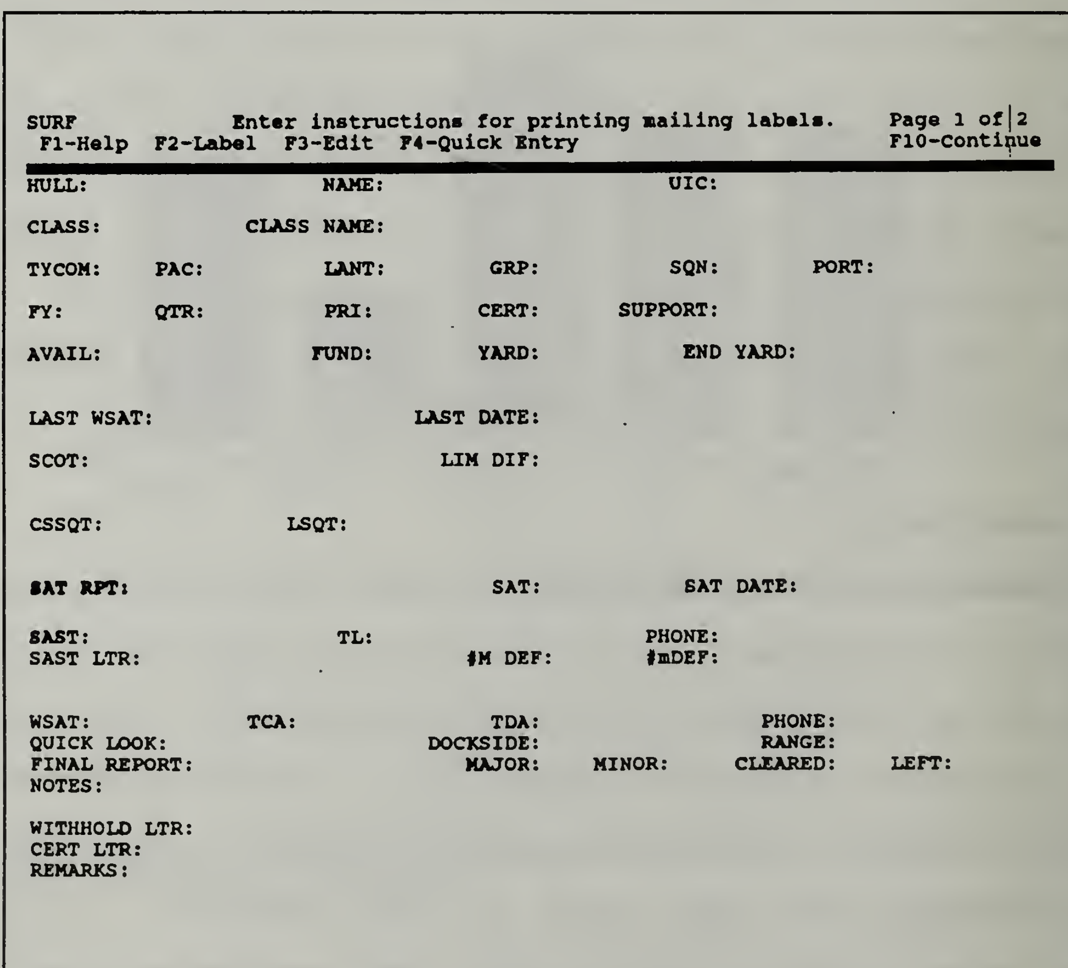
The WSAT data base is managed by the NAVSEA ASW test program office (NAVSEA 06UT). It is the product of efforts by STGCS(SW) W.J. Vick, USN. It was designed to be an all inclusive information system containing relevant historical information concerning ASW testing conducted by NAVSEA on both surface ships and submarines. Additionally, it is intended to be used as an aid in forecasting future testing requirements based on long range ship repair and conversion plans. The information in the centralized data base is compiled from many different sources. The data base is currently managed by Mr. Peter Karounos (NAVSEA 06UT) who is assisted by STGCS(SW) J. Brown, USN. As a centralized data base, NAVSEA retains responsibilities for both data integrity and security.

B. ORGANIZATION

The latest printed edition of the WSAT ASW test data base is dated 16 September 1991 and is organized into two parts. Part one is information relevant to surface ships. Part two is information relevant to submarines. Further discussion will be limited to the surface ship section of the data base in accordance with the scope of this analysis. As a microcomputer based software data base management system

written on the commercially available *PFS:Professional File Version 2.02*, the data base is easily learned and manipulated.

G. Hanson and J. Hanson in *Database Management and Design* [Ref. 4:pp 15] describes a microcomputer data base management system as a system that demonstrates query flexibility and ease of data base creation and maintenance. This package meets those prerequisites. The surface ship data base currently comprise 51 data fields of various types (ie: date, numeric, alphanumeric, etc...). Figure 10 displays the relevant data fields being used.


SURF Enter instructions for printing mailing labels. Page 1 of 2
F1-Help F2-Label F3-Edit F4-Quick Entry F10-Continue

HULL: NAME: UIC:
CLASS: CLASS NAME:
TYCOM: PAC: LANT: GRP: SQN: PORT:
FY: QTR: PRI: CERT: SUPPORT:
AVAIL: FUND: YARD: END YARD:

LAST WSAT: LAST DATE:
SCOT: LIM DIF:

CSSQT: LSQT:

SAT RPT: SAT: SAT DATE:

SAST: TL: PHONE:
SAST LTR: #M DEF: #mDEF:

WSAT: TCA: TDA: PHONE:
QUICK LOOK: DOCKSIDE: RANGE:
FINAL REPORT: MAJOR: MINOR: CLEARED: LEFT:
NOTES:

WITHHOLD LTR:
CERT LTR:
REMARKS:

Figure 10. WSAT Data Base Fields

C. CRITICAL EXAMINATION

PFS:Professional File is a flexible software application package which is very similar to *Data Base III*. The comprehensive use of pull down menus and on line help functions make it quite adaptive to the novice user, yet it also has many short cut features suited to the advanced operator. Although the software system is more than adequate for the job, the data base itself has several aspects needing revision to ensure continued usefulness. Critical examination indicates that while a basis for corporate information system management is present, approximately 8 data fields in the data base are either obsolete or unnecessary. This statement is substantiated by the appalling lack of data in these fields and the insignificance of the information in others. A complete printed report of the entire data base requires 4 pages to intelligently convey all information on each ship. It is obvious upon examination that the data base is primarily an administrative aid to track ASW testing, scheduling, and associated correspondence. Unfortunately, the usefulness of the data base in identifying material discrepancy trends is limited in the current format. Although the number of discrepancies are listed for each ship inspection, it fails to identify equipment specifics or even the associated material categories. This information will be statistically significant in planning future inspections or other

certification procedures. This statement is even more true in a time of budget shortfalls and constraints, which appear to be a permanent fixture associated with the conclusion of the cold war.

As future certification procedures evolve, probably based on cost overhead, it would be imprudent to ignore material trends where risks resulting from non-testing are too great. The problem of manpower in maintaining the ASW test data base might be addressed by changing from a centralized data base management system to a distributed system connected via modem. This would spread the chores of data entry to the requisite inspection activities and put NAVSEA in a more supervisory role. The network could conceivably consist of only 5 sites which is easily manageable. With the unclassified nature of the data base and the use of commercial phone lines, this concept is certainly economically feasible. Specific recommendations on data base field deletions and additions will be included in Chapter VI of this study.

IV. ANALYSIS OF DATA

A. ANALYSIS ASSUMPTIONS

As the scope of the ASW test and certification program, specifically WSAT, undergoes dynamic changes to meet funding restrictions, the question of which material categories historically demonstrate the most discrepancies should be examined. If the WSAT core structure inspection is reduced without regard to this, then it is an implicit assumption that material degradation is homogenous throughout the five material categories in the WSAT. Although WSAT describes inspection discrepancies as either major or minor in nature, this analysis will weigh all discrepancies equally for conducting the multinomial experiment. Accordingly our N = 595 data points will be individually assigned to one of five material categories. The variable p_i will represent the probability that any individual discrepancy belongs in material category i (i=1.....5).

A. NULL AND ALTERNATE HYPOTHESIS

In order to conduct a statistical test on the data, a specific hypothesis to be refuted must be defined. For this analysis the null hypothesis will be that any particular observation is equally likely to fall in any one of

the five WSAT material categories described in chapter II, that is $p_1=p_2=p_3=p_4=p_5$. The alternate hypothesis to be substantiated via testing is that at least one category proportion is not equal to the others. Equation 1 summarizes the null hypothesis:

$$\begin{gathered}\textit{NULL HYPOTHESIS}\\ H_o : p_1 = p_2 = p_3 = p_4 = p_5 = .20\end{gathered} \tag{1}$$

Equation 2 summarizes the alternate hypothesis:

$$\begin{gathered}\textit{ALTERNATIVE HYPOTHESIS}\\ H_a : \textit{At least one } p_i \neq .20\end{gathered} \tag{2}$$

B. STATISTICAL TESTING OF HYPOTHESIS

A standard test procedure for this hypothesis is described in Devore, *Probability And Statistics For Engineering And The Sciences* [Ref. 5:pp 556-559]. The name of this procedure is the chi-squared goodness-of-fit test for categorical data. The null hypothesis is rejected in favor of the alternative hypothesis if a test statistic is too large. The test statistic is labeled a χ^2 (chi-square) statistic and is defined in Equation 3

$$\chi^2 = \sum_{i=1}^{5} \frac{(n_i - e_i)^2}{e_i} \tag{3}$$

where n_i is the number of the total N = 595 observations that fall into each material category i (i=1,2,3,4,5) found in Chapter II, Figure 9. The variable e_i is the expected number of the 595 observations for each category i as calculated in Equation 4.

$$e_i = p_i(N) = (.20)(595) = 119 \tag{4}$$

When the null hypothesis is true, the observed number of category discrepancies should be close to the corresponding expected values and the test statistic should be small. Provided that the expected value, e_i, is greater than or equal to 5 for each category, the test statistic has a chi-squared distribution with ν = 5-1 = 4 degrees of freedom. The decision to accept or reject the null hypothesis will be accomplished by comparing the computed value of the test statistic to an appropriate critical value of the chi-squared distribution, which is tabulated and available in most statistics text books. The critical value for the test procedure will be determined by choosing a significance level, α , for the hypothesis test. The value of α is the probability of rejecting the null hypothesis when it is true. The critical value is the 1-α percentile point of the chi-square distribution with 4 degrees of freedom. For α =.01 and ν = 4 the tabulated critical value is 13.277.

This means we reject our null hypothesis if the calculated test statistic is greater than 13.277. Equations 5 through 7 summarize the Navy wide chi-square test respectively.

$$\begin{gathered} \textit{Reject } H_o \ (p_i = .20) \textit{ if} \\ \chi^2 \geq \chi^2_{\alpha,\nu} \end{gathered} \tag{5}$$

$$\begin{gathered} \textit{The } \chi^2 \textit{ test statistic defined by equation } (3) \\ \chi^2 = \frac{(117-119)^2}{119} + \frac{(56-119)^2}{119} + \frac{(163-119)^2}{119} \\ + \frac{(130-119)^2}{119} + \frac{(129-119)^2}{119} = 51.51 \end{gathered} \tag{6}$$

$$\begin{gathered} \textit{The tabular distribution critical value is} \\ \chi^2_{.01,4} = 13.277 \\ \textit{as a result, since} \\ \chi^2 = 51.51 \geq \chi^2_{.01,4} = 13.277 \text{-------}\rightarrow \textit{Reject } H_o \end{gathered} \tag{7}$$

The conclusion, based on this test procedure, is to reject the null hypothesis of homogenous material category degradation in favor of the alternate hypothesis. There is very strong statistical evidence indicating significant differences in Navy wide WSAT material category reliability to support the alternative hypothesis.

The next step in the analysis will be to determine if the Atlantic Fleet data refutes the same homogenous null hypothesis. Using observed discrepancy values from Chapter

II, Figure 7, the pertinent variables are summarized in Equation 8 through 10.

$$N = 261 \qquad p_i = .20 \qquad e_i = (.20)(261) = 52.2 \tag{8}$$

The χ^2 *test statistic is*

$$\chi^2 = \frac{(55-52.2)^2}{52.2} + \frac{(30-52.2)^2}{52.2} + \frac{(70-52.2)^2}{52.2} + \frac{(67-52.2)^2}{52.2} + \frac{(39-52.2)^2}{52.2} = 23.20 \tag{9}$$

$$\chi^2 = 23.20 \geq \chi^2_{.01,4} = 13.277 \text{ ---------} \rightarrow \textit{Reject } H_o \tag{10}$$

Accordingly, testing of the Atlantic Fleet data also supports rejecting the null hypothesis in favor of the alternative hypothesis that at least one p_i is not equal to .20 .

The last step in the test will be to check that the Pacific Fleet data also refutes the null hypothesis. Using the data from Chapter II, Figure 8 the variables for the test are summarized in Equations 11 through 13.

$$N = 334 \qquad p_i = .20 \qquad e_i = (.20)(334) = 66.8 \tag{11}$$

The χ^2 *test statistic is*

$$\chi^2 = \frac{(62-66.8)^2}{66.8} + \frac{(26-66.8)^2}{66.8} + \frac{(93-66.8)^2}{66.8} + \frac{(63-66.8)^2}{66.8} + \frac{(90-66.8)^2}{66.8} = 43.82 \tag{12}$$

$$\chi^2 = 43.82 \geq \chi^2_{.01,4} = 13.277 \text{ ---------}\rightarrow \textit{Reject } H_o \qquad (13)$$

Like the Navy wide data and the Atlantic Fleet data, the Pacific Fleet data also strongly supports rejecting the null hypothesis in favor of the alternative hypoyhesis.

Having tested the data in the aforementioned fashion, it is now an accurate statement to say that a homogenous degradation in the five material categories of WSAT is false. Chapter V will address specific recommendations on which category to focus attention on and which categories are least prone to failure.

V. CONCLUSIONS AND RECOMMENDATIONS

A. WSAT ANALYSIS

1. Conclusions

The analysis of the last five years of WSAT data conducted in Chapter IV strongly indicates the variation in degradation among the five material categories which comprise WSAT. Figures 11 through 13 summarize the experiment results for the Atlantic Fleet, Pacific Fleet, and Navy wide data respectively.

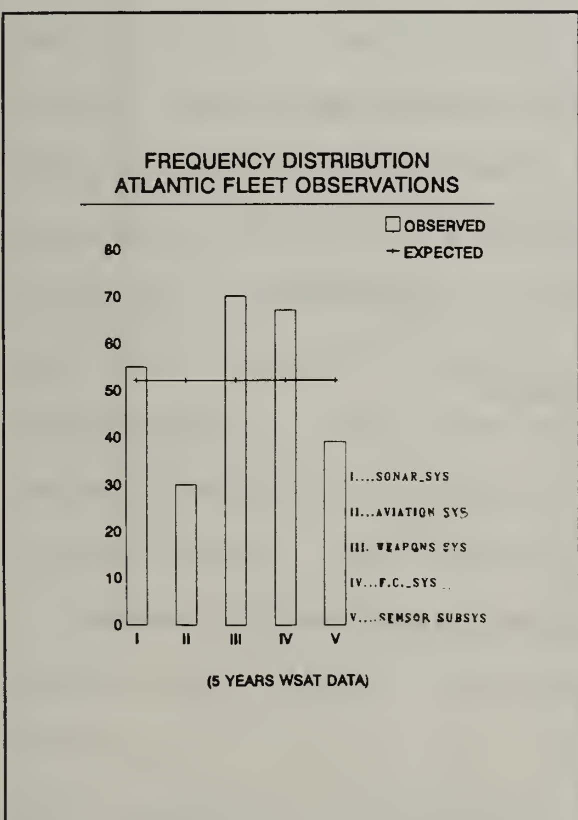


Figure 11. Atlantic Fleet Results

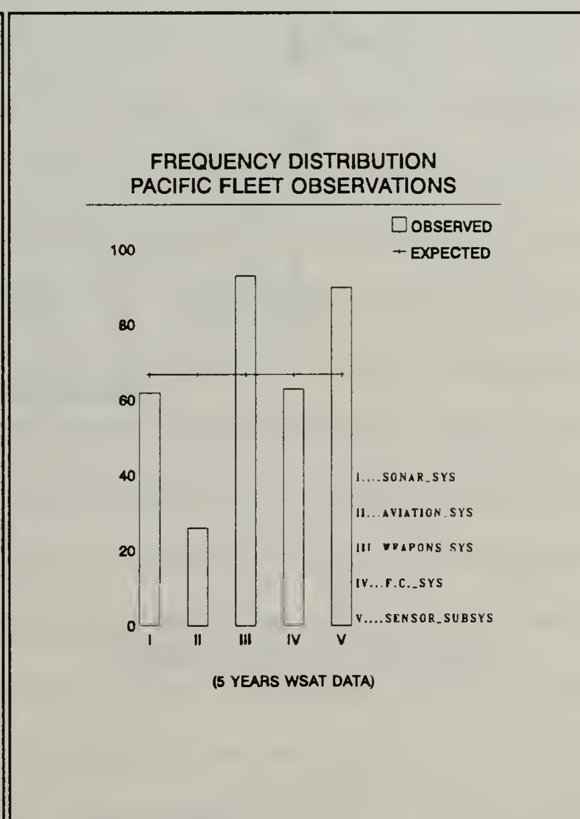


Figure 12. Pacific Fleet Results

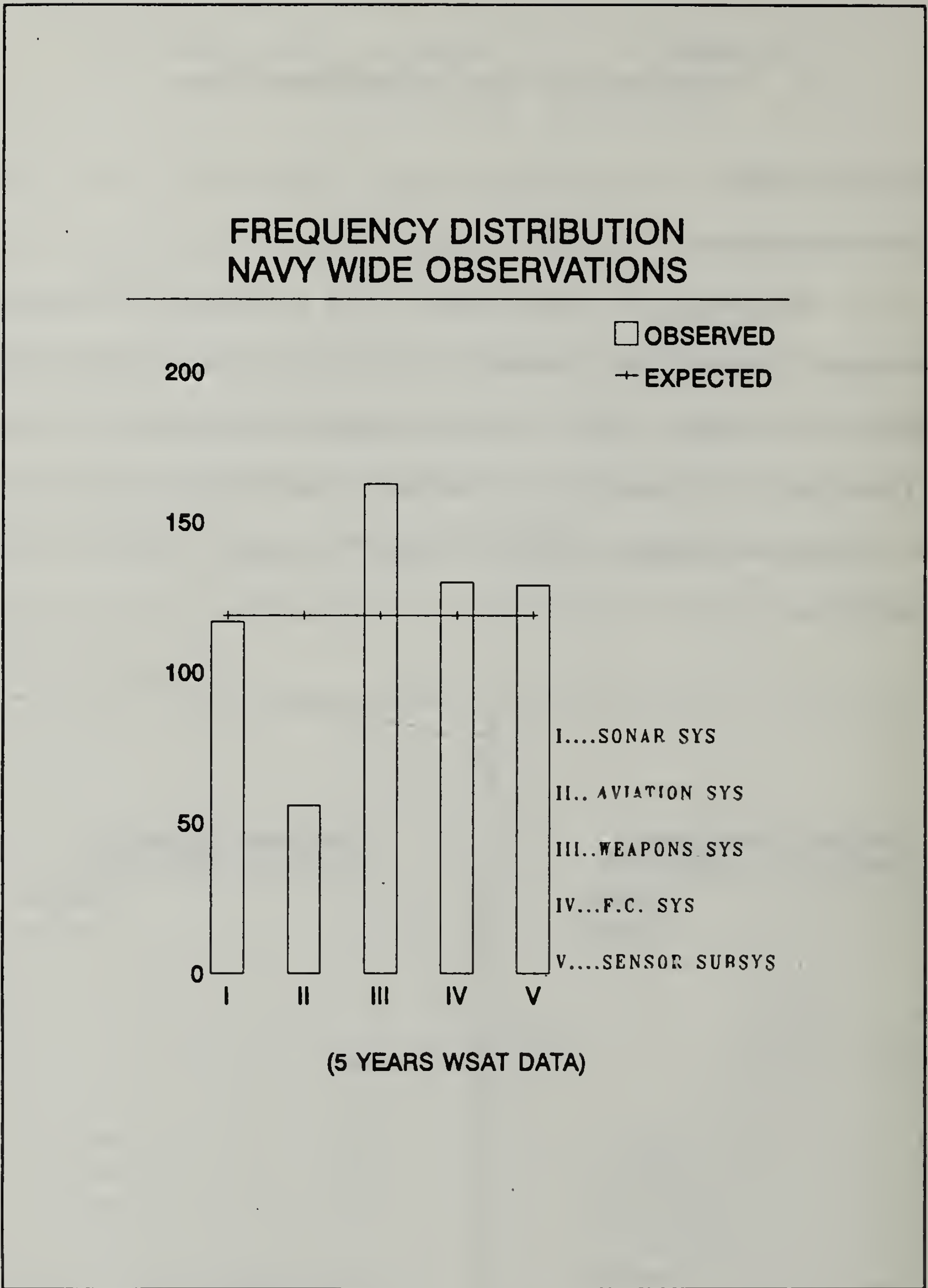


Figure 13. Navy Wide Results

The Navy wide material categories rank from least prone to failure to most prone to failure as follows:

- NAVY WIDE RELIABILITY RANKING
    1. Aviation Systems (Cat II)
    2. Sonar Systems (Cat I)
    3. Sensor Subsystems (Cat V)
    4. Fire Control Systems (Cat IV)
    5. Weapons Delivery Systems (Cat III)

The discrepancy most common in the least reliable category was undeniably found to be in torpedo launcher systems. Improper tube firing voltages, firing pressures, and interface failures were prolific in the 163 data points in this category. This is not surprising considering the fact that most torpedo launcher systems have at least partial exposure directly to an ocean environment with detrimental effects on electrical and mechanical components. Figure 14 provides for direct comparison between Atlantic and Pacific Fleet observed discrepancies. In 3 of 5 categories the Pacific Fleet ASW systems demonstrate a greater propensity for failure than the Atlantic Fleet. The largest variation found was in category V (Sensor Subsystems) where the Pacific Fleet showed significantly higher numbers of discrepancies than its contemporary (90 vice 39). Subsequent reexamination of the data revealed a prevalence of discrepancies in NTDS/CDS software on Pacific Fleet Ticonderoga class guided missile

cruisers. These most recently delivered ships contain the most current software versions which apparently are replete with certification discrepancies. The other differences in Fleet data are small in comparison but have no apparent rational explanation. One would expect that uniform technician training standards and maintenance procedures would minimize this variance. The only other possible explanation might be a function of East Coast and West Coast Test Activity inspector personalities and background experience.

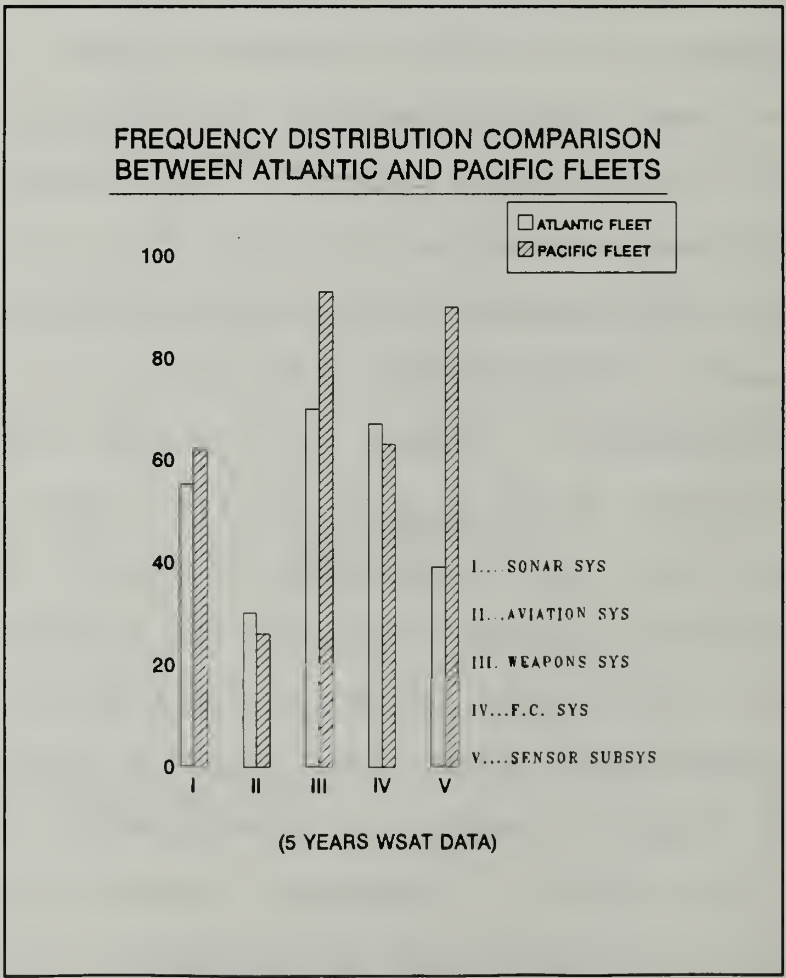


Figure 14. Fleet Data Comparison Summary

2. Recommendations

The following recommendations apply to the future of the ASW Test Program:

1. Focus future inspection packages with emphasis on torpedo tube and ASROC launcher validation by experienced technicians.

2. Establish revised, precise tactical digital standards for certification of software based systems.

3. If 3-D range firing exercises must be eliminated, conduct a comprehensive study of past range data to determine failure cause and results. Incorporate these findings in test program development.

4. Include any available ASW PACER data in development or assessment of a ship ASW certification.

5. Conduct ongoing statistical analysis of ASW combat systems discrepancy trends. The CASREP data base, maintained at the TYCOM level, is an excellent source of current Fleet system problems.

6. Incorporate future WSAT (or equivalent) data into ongoing statistical analysis.

7. Conduct a study to compare WSAT historical trend results with current Fleet equipment reliability prediction programs such as the Trouble Systems Process developed by Vitro Corporation.

8. Conduct a comparative study of ASW technical training standards between Fleet training centers with a goal of uniformity.

B. WSAT DATA BASE ANALYSIS

1. Conclusions

The critique of the existing WSAT data base in Chapter II found a comprehensive, centralized data base requiring only

minor modification. The key issues are to examine the implementation of a distributed network data base and subsequent modification of data base fields to promote statistical analysis.

2. Recommendations

The following recommendations apply to data base field structure:

- Fields Recommended For Deletion

  1. GRP/SQN/PORT: All of these fields are variable over a ships life. They are available elsewhere and actually provide little information relative to the ASW Test Program.

  2. CSSQT: This is no longer a funded program.

  3. SCOT: This field contains minimal existing data which attests to its invalidation.

  4. SAST/SAST LTR: Only one inspection was conducted under this program prior to discontinuation.

  5. TDA/PHONE #: This field also has no existing data. Test agency phone numbers are variable as shore commands evolve and are available elsewhere.

  6. REMARKS: This field exhibits minimal existing data which attests to its invalidation.

- Fields Recommended For Addition

  1. A material category discrepancy breakdown field which would provide an adequate means of recording observed discrepancies in an orderly fashion and promote statistical analysis. The following numeric field format would suffice: --/--/--/--/--.

LIST OF REFERENCES

1. Naval Sea Systems Command, Technical Manual OD 40087,p.1-1, Fourth Revision.

2. Steigman, David S., *Navy Times*, p.4, April 1992.

3. Naval Sea Systems Command, Technical Manual TW000-ac-MAN-010/SAST, p.1-2, 1st ed.

4. Hanson, G. and Hanson, J., *Database Management and Design*, p.15, Prentice-Hall Inc., 1992.

5. Devore, Jay L., *Probability and Statistics for Engineering and the Sciences*, pp.556-559, 2nd ed., Brooks/Cole Publishing Company, 1987.

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